AN UNUSUAL SHELL DEPOSIT AT POINT RITCHIE, WARRNAMBOOL, VICTORIA – PREDATOR MIDDEN OR NATURAL SHELL DEPOSIT?

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Turbo undulatus (Lightfoot, 1786) shells form an almost mono-specific assemblage approximately 8m above present sea level at Point Ritchie. The shell deposit occurs in two locations – as a surficial scatter on a now partly collapsed rock stack and as *in situ* material in a calcarenite layer on the adjacent headland. Stratigraphic investigations and dating using radiocarbon, thermoluminescence, amino-acid racemisation and ESR techniques show the deposit was formed prior to the eruption of Tower Hill volcano (~35ka) with a most likely age of 60 – 80ka. At the time of its formation the shell assemblage was deposited above its contemporaneous sea level in a terrestrial environment. The absence of water rounding in shells and clasts and other characteristics indicate the deposit is unlikely to be storm beach or tsunami deposit. It is most likely a midden although the identity of the species responsible is not known. The deposit does show many similarities to human middens but lacks artifacts or human skeletal material. It is an enigmatic deposit which has generated considerable interest because of the implications it would have for the arrival time of the first Australians if it was established as human in origin.

Key words: Turbo undulatus, shell bed, midden, dating, sea level

POINT Ritchie is located on the western side of the mouth of the Hopkins River, Warrnambool, Victoria (Fig. 1). It is the site of a shell deposit containing both marine and terrestrial molluscan species, crustacean and fish remains and charcoal. The site's elevation (>8m above present sea level), unusual species assemblage and the absence of water rounding amongst the angular broken shell fragments and cobbles present in the deposit, led to a hypothesis that the site was an Aboriginal shell midden (Prescott and Sherwood 1988). Subsequently a detailed study established a most likely age of 60 ± 20ka for the deposit (Sherwood et al 1994). This age assignment was based on data obtained from thermoluminescence (TL), electron spin resonance (ESR), amino aci racemisation (AAR) and carbon-14 (^{14}C) techniques. Uranium series dating was attempted but proved unsatisfactory since shells did not behave as closed systems. An Aboriginal shell midden of this antiquity would have important implications for the arrival time of the first Australians.

A number of Pleistocene Australian archaeological sites have been studied and dated. While the validity of some of these dates has been questioned (see O'Connell and Allen 2004) none of them indicate the arrival of humans in Australia before ca. 60 – 70ka (Bowler et al 2003; Thorne et al 1999; Roberts et al 1994). While the presence of humans by ~30 – 45ka at Bluff Cave, Tasmania (Cosgrove 1989) and Devil's Lair, Western Australia (Turney et al 2001) indicates that by this time Aborigines had traveled to the western- and southern-most regions of the continent the oldest marine middens in the southeastern Australian region date at ~9.5 – 10ka (Cann et al 1991, Godfrey et al 1995: Table 4). Pleistocene middens formed close to the coast at lower relative sea level would be drowned when the sea advanced however.

We report here the first detailed site description of the Point Ritchie shell deposit and analyse evidence supporting an origin for it based on either predator selection (i.e. the site is an animal, possibly human, midden) or geo-physical processes (i.e. a "natural" shell deposit).

FIELD SURVEYS

Some information on the site was collected during field visits by one of us (JS) with E.D. Gill (now deceased). He originally recognized the potential significance of the site and his personal notebooks were the source of some of the site information reported

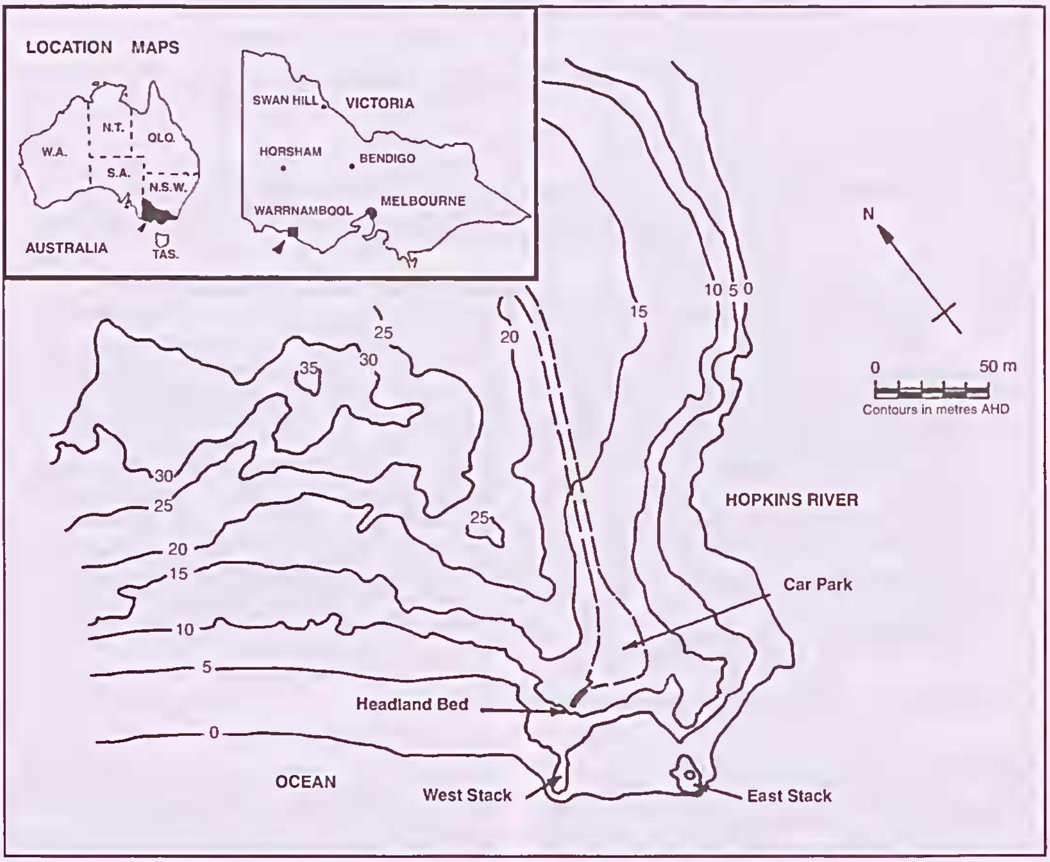


Fig. 1. Locations of the shell deposit at Point Ritchie, the western headland of Warrnambool's Hopkins River estuary.

here. Those of Gill's field notebooks which cover western Victoria are presently held at Deakin University's Warrnambool campus library.

Specimens collected from the site, particularly those eroding from the Headland Deposit are curated at Deakin University's Warrnambool campus.

Quadrats and Species Counts. Quadrats (25cm x 25 cm) were randomly placed in three areas of dense shell accumulation on West Stack. The location of these quadrats was noted. All loose surface material was brushed away with a large paint brush before counts were undertaken to avoid counting any material that was not *in situ*. Once loose material was removed counts were made of all identifiable shell fragments (Table 1). To avoid double-counting, counted shells were marked with a black dot. Species counts from the headland deposit were undertaken on specimens collected by Edmund Gill, John Sherwood and Hannah Nair.

SITE LOCATION AND STRATIGRAPHY

Warrnambool is located on the south west coast of Victoria (lat. 38°23' S long. 142°29' E). At its eastern edge it is flanked by the estuary of the Hopkins River (Fig. 1). The estuary extends approximately 9 km upstream. At the estuarine limit the river is barred by a basalt lava flow which infills an old course of the Hopkins River dated by K/Ar at 650ka (Gill 1981). For most of its length the estuary occupies a drowned river valley cut into Port Campbell Limestone – a marine calci-siltite of Miocene age (Gill 1943). Near the mouth a series of cemented calcareous aeolian and shallow water marine formations overlie the Port Campbell Limestone.

At the western side of the estuary mouth is a rocky headland, Point Ritchie (Fig. 1). Holocene uncemented calcareous sands cap this headland and also constitute the eastern side of the estuary mouth where they have collected as a dune under the influ-

ence of prevailing south west winds. South of the headland are two rock stacks – East and West Stack – cut off from the headland by coastal erosion. The shell deposit of interest in this paper is exposed in two situations:

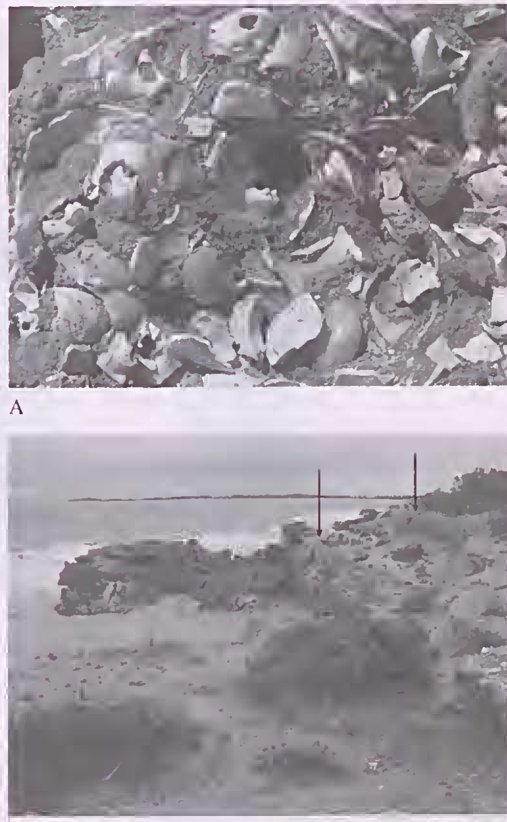
(a) In the headland itself where marine shells and charcoal are exposed by erosion of a calcarenite sand between two calcrete layers (referred to as "upper" and "lower" calcrete). This deposit is referred to as the "Headland Deposit"
(b) On the surface of a large rifted and tilted rock slab which has fallen from a promontory which juts into the sea, referred to as the "West Stack Deposit" (Fig. 2).

Stratigraphy of Point Ritchie Headland

East Stack is composed of a cross-bedded calcarenite – the oldest material exposed at Point Ritchie headland. This also forms the base of a valley fill sequence in both the headland and West Stack (Fig. 3). Oyston (1996) determined the age of this basal unit as 263 ± 30ka using the thermoluminescence method. The material that forms East Stack is a highly cemented dune aeolianite containing numerous rhizomorphs (evidence the dune was once vegetated). It is referred to throughout this paper as the East Stack Calcarenite.

Overlying the East Stack Calcarenite on the headland is a terrestrial sequence occupying a small valley or swale. This valley is exposed in the south-west cliff of Point Ritchie and its floor dips to the north-east. On the eastern side of the headland the valley floor goes below sea level, indicating a lower sea level at its formation. A previously described calci-siltite loess (Gill and Segnit 1982) is the oldest member of the terrestrial sequence infilling the valley (Fig. 3).

A calcarenite sand coloured 7.5 YR 5/4 (strong brown) to 10 YR 7/4 (very pale brown) overlies the loess. The sand is generally cemented and contains small rounded flat pieces of marine shell (<10mm dia.) suggesting proximity to the sea. Cross-bedding and rhizomorphs are present. On the sand is a thick terra rossa soil. Its colour varies from 2.5 YR 5/4 (reddish brown) to 2.5 YR 4/6 (red). The terra rossa soil contains fossil planispiral snails and small rhizomorphs suggesting it was associated with low scrub i.e. dry, or seasonally dry conditions. It is cemented into a solid band and includes pieces of grey to black, mostly angular, calcrete. Above this the sequence



A

B

Fig. 2. A: The shell deposit on the surface of West Stack, Point Ritchie. Scale: 20 mm = 35 mm. B: View from Point Ritchie headland, showing the West Stack block (top left of photo) and the Headland Deposit (right). Note the upper and lower calcrete layers of the Headland Deposit (arrowed).

consists of inter-bedded calcarenites and terra rossa soils. Thin calcretes (< 50mm) are associated with the soils. Sherwood et al (1994) and Oyston (1996) obtained a consistent series of TL ages for these valley fill deposits showing they had accumulated between 100ka and 200ka.

At the top of this sequence a horizontal calcrete layer (the "lower calcrete") sits unconformably over the valley beds (Fig. 2B). In places traces of an overlying terra rossa (5 YR 5/4 "reddish brown") remain but this has generally been stripped away. The calcrete varies greatly in thickness, in places it is up to 1.25m. A second calcrete (the "upper calcrete") shows very similar properties – traces of its associated terra-rossa soil (7.5 YR 5/4 "strong brown") occur above it. The calcarenite (7.5 YR 6/4 "light

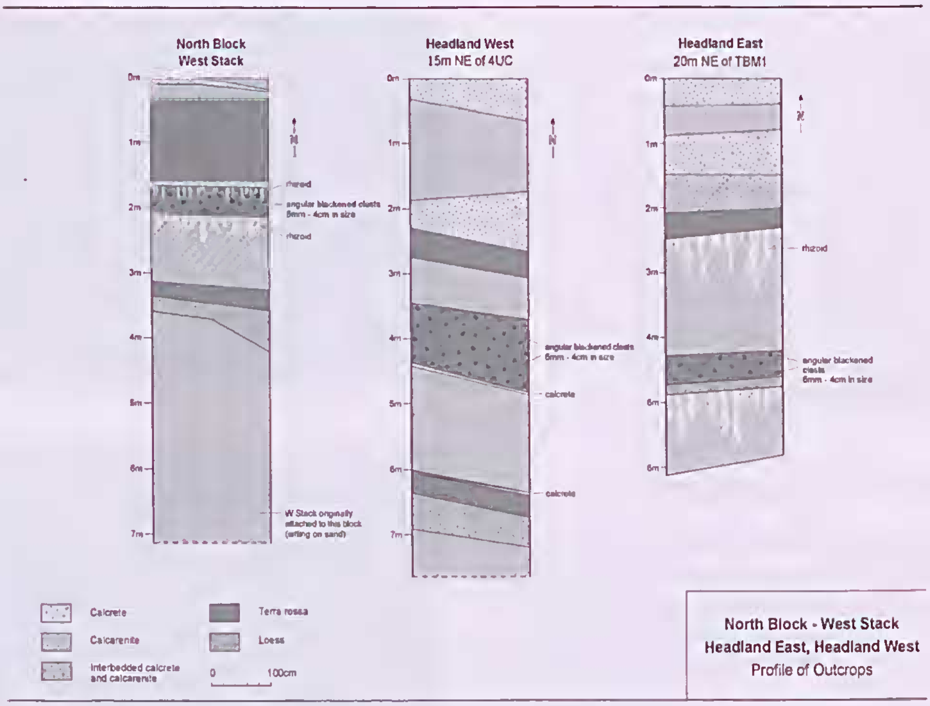


Fig. 3. Stratigraphic sections of West Stack and the south facing cliff of Point Ritchie headland (one on the west and one on the east side of the cliff). The two uppermost calcrete layers in the headland sections represent the "upper" and "lower" calcretes. These contain the Headland deposit. The lower calcrete corresponds to the layer seen at the top of the West Stack profile (which contains the West Stack deposit). The 'N' symbol indicates the profiles are represented facing north.

brown") lying between the upper and lower calcretes has been identified as a small exposure of the Dennington Sand (Gill 1976) formed ~100ka – 70ka (Oyston 1996). Marine fossils have been found eroding from this calcarenite along an exposure of ~90m on the south edge of the headland.

This calcarenite also contains numerous terrestrial snails and rhizomorphs. From the habitat preferences of these snails (Table 2) it would seem the calcarenite supported a scrub or heathland in a dry and/or coastal region (Smith and Kershaw 1979). The calcarenite has locally hardened areas but is generally soft (penetrometer readings 3.5 to 4kg. cm). Erosion of the calcarenite has led to deep undercutting (up to 2m) of the upper calcrete in places. A third calcrete layer (the "middle calcrete") approximately 150mm thick occurs within the calcarenite as the upper and lower calcretes diverge towards the west of the headland. It represents an intermediate period of soil formation.

Above the upper calcrete is a thin laminated mamillary calcrete less than 10mm thick. A brown soil containing Tower Hill Tuff covers the calcrete except near the cliff edge where it has been stripped away by wind erosion. This soil thus post-dates the Tower Hill eruption which has been dated at 35 ± 3ka (Sherwood et al 2005). A midden in this soil gave a radiocarbon age of 3.9 ± 0.05ka (SUA 2016) based on shells of *Turbo undulatus*, the dominant species present.

Yellow-brown, free flowing calcarenite sand forms the uppermost unit in the sequence and contains immature grey soils. A midden exposed in one of these soils at the west of Point Ritchie had a radiocarbon age of 1 ± 0.2ka (SUA 1615). This age was again determined on *T. undulatus*, the dominant midden species.

Stratigraphy of West Stack

The upper portion of this stack has been undercut and has subsequently split and collapsed into three pieces. To the east the largest slab now lies at a steep angle on the beach, resting against the lower portion of the stack. Another piece, now itself split in half,

QUADRAT NO.	SPECIES	COUNT*	SIZE RANGE+
WSSouth1 57cm south of north edge and 2m from east edge of west stack south block.	*Turbo undulatus* (Lightfoot, 1786)	24	1.9cm – 4.7cm
	Turbo undulatus (operculae)	3	0.4cm – 2.2cm
	Turbo torquatus (Gmelin, 1791) (operculum, incomplete)	1	2.90cm
	Hipponyx conicus (Schumacher, 1817)	5	0.9cm – 2.0cm
	Unidentifiable fragments	206	0.1cm – 4.0cm
WSNorth1 55cm north of south edge and 1.3m from west edge of west stack north block.	*Turbo undulatus*	20	0.9cm – 3.1cm
	Turbo undulatus (operculae)	2	0.7cm – 2.2cm
	Hipponyx conicus	3	1.3cm – 1.8cm
	Unidentifiable fragments	285	0.05cm – 3.2cm
WSNorth2 29.5cm north of south edge and 24cm from west edge of west stack north block.	*Turbo undulatus*	13	2.3cm – 3.1cm
	Turbo undulatus (operculae)	5	0.8cm – 1.9cm
	Hipponix conicus	3	1.7cm – 2.1cm
	Thais orbita (Gmelin, 1791)	1	7.0cm
	Unidentifiable fragments	183	0.1cm – 3.4cm

* Shells counted possessed a columella and had one or more whorls intact. This gives a minimum estimate of the number of individuals.

\+ *Turbo undulatus* shells and operculae, *Turbo torquatus* operculae, *Hipponyx conicus* shells measured at widest point. Length of *Thais orbita* measured.

Table 1. Species composition and size ranges for 3 quadrat surveys (each 625cm^2) of the West Stack deposit.

fell to the west and also rests against the lower portion of the stack. Their once horizontal surfaces now dip to the west at an angle of approximately 15°. The West Stack block appears to have become separated by erosion from the main headland section and corresponding strata can be seen in the stratigraphic diagrams (Fig. 3) of the detached West Stack block and the main headland section. The calcrete layer containing the West Stack deposit is represented in the main headland section as the 'lower calcrete' (Fig. 3).

The West Stack shell deposit covers ~7m^2 and comprises highly fragmented and angular shell material, along with some near- or complete shells embedded in a cemented calcarenite sand (Fig. 2A). The calcarenite sand is underlain by a calcrete of variable thickness (<5mm to 300mm). At one site it is overlain by a possibly residual capping block of calcrete (~300mm square and 50 – 100mm thick). Thin (<5mm) laminated calcretes are interleaved with the calcarenite sand and calcrete slabs up to 50mm thick occur embedded in it. Rhizomorphs run through the calcarenite and along the surface of the lower calcrete. This shell deposit is less than 100mm in thickness and is referred to as the West Stack deposit throughout this paper. The high degree of fragmentation of the shell is consistent with this deposit being a lag deposit – wind-winnowing of sediment has left the relatively thin layer of predominantly broken shell and cobbles now cemented together.

Blackened clasts occur together with shell material on the West Stack block. Thermoluminescence studies suggest these stones have not been strongly heated and so they may not be hearth stones as their appearance suggests (Sherwood et al 1994).

Last Interglacial Storm Beach Deposits

Nine lenses of mostly rounded pebbles, boulders and shell fragments embedded in coarse sands have been found attached to the East Stack Calcarenite or filling notches cut in it. *Turbo undulatus* is the dominant species present in the lenses but *T. torquatus* Gmelin, 1791 operculae have been found in three lenses. The latter is not known in deposits younger

than the Last Interglacial in Western Victoria (Valentine 1965). A radiocarbon age on *T. undulatus* collected from a lens on the East Stack gave an age of 41.2 (+2.7/-2.0) ka (SUA 2020) and is interpreted as at the limit of the method. This is supported by ESR dating which suggests a Last Interglacial age (Goede 1989; Sherwood et al 1994). The lenses occur to a maximum height of approximately 4m above present sea level and appear to be the remains of a storm beach deposit of Last Interglacial age, perhaps corresponding to the +4m sea level peak of 110ka (Gill and Amin 1975).

DATING OF THE WEST STACK DEPOSIT

A number of techniques have been used to date the Headland and West Stack shell deposits at Point Ritchie (Sherwood et al 1994). The reported age of 60 ± 20ka is based on determinations by AAS, ESR, TL and ^{14}C techniques. The age of the shell deposits must exceed that of the Tower Hill tuff (35 ± 3ka (Sherwood et al 2005) based on their relative stratigraphic positions. Radiocarbon age determinations based on shells and charcoal samples from the headland deposit were not concordant (i.e. the ages did not overlap within 3 standard deviations; Sherwood et al 1994). Aragonite, present in mollusc shells, can recrystallise over time to form calcite (Head 1991) and materials in which recrystallisation has occurred approximate an open geochemical system (Chappell and Pollach 1972). This allows older materials to become contaminated with younger ^{14}C, resulting in a false, younger radiocarbon age (Chappell and Polach 1972). The skeletal carbonate of molluscs is very susceptible to recrystallisation and material recrystallised as sparry calcite cannot yield a reliable ^{14}C age (Chappell and Polach 1972). Calcium carbonate leached out of rocks can also have an effect on the ^{14}C content of a shell (Yates et al 2002).

As part of this study a further radiocarbon date was measured for *Turbo undulatus* shell material obtained from the West Stack deposit. It gave an age of >40ka (Wk – 17335). Physical pretreatment of the shell material involved cleaning of its surfaces, washing in an ultrasonic bath and testing for recrystallisation of aragonite to calcite. The sample was then chemically pretreated by acid washing using 2M dilute HCl for 150 seconds, rinsed and dried. Advice received from the University of Waikato Radiocarbon Dating Laboratory stated the age of the shell material was beyond the scope of the conventional radiocarbon method. The Waikato Laboratory also advised that no recrystallisation of aragonite to calcite appeared to have occurred in the sample.

This supports the view of Sherwood et al (1994) that other apparently finite ^{14}C ages exceeding 30 ka are most likely unreliable for this site.

Three dating techniques other than ^{14}C have been used to estimate the age of the shell deposits. Two of these give relative ages (Electron Spin Resonance (ESR) and Amino Acid Racemisation (AAR)) while Thermoluminescence (TL) gives an absolute age subject to assumptions about dose rates and moisture content of sediments over the time since deposition. ESR and AAR use shell material while TL tests quartz grains in the sediment matrix. TL determinations by Sherwood et al (1994) and Oyston (1996) gave ages of 67 ± 10ka and 93 ± 11ka respectively. Goede (1989) assigned a late Last Interglacial age to the shell deposit based on ESR dating. The site's equivalent dose (106 +9/-7 Gray) was significantly lower than a late Last Interglacial shell deposit at Goose Lagoon (187 Gray) and the storm beach deposits at Point Ritchie (149 +15/-19; 126 +39/-26 Gray). AAR gave a relative age intermediate between Holocene and the Last Interglacial based on shells from Goose Lagoon and elsewhere. The Goose Lagoon shell deposit (elevation = 3.2m AHD) has been recommended as a Last Interglacial reference site for western Victoria because of the concordance of age determinations for all dating techniques. It gave U/Th ages of 95 -101ka, a Pa/U age of 86 ± 8ka and a Pa/Th age of 109 ± 18ka based on 4 shell samples (Sherwood et al 1994).

Collectively these age determinations support a late Last Interglacial age for the shell deposit – most likely the 80ka sea level maximum during which the Dennington Sand was deposited.

SPECIES COMPOSITION OF THE POINT RITCHIE DEPOSITS

Analysis of the species composition of a deposit can provide information about its environment of deposition, evidence of anthropogenic or zoological (for example, by birds) selection of species as a food resource and evidence for size selection of shells due to predator behaviour or sorting of sediments by physical processes such as wind or wave action. In addition to ascertaining what species are present in the Point Ritchie deposit, species composition analy-

sis provided information on relative abundance and size range of species.

West Stack deposit

This deposit appears to contain a very limited fauna, comprised largely (among the identifiable material) of the edible rocky shore gastropod *Turbo undulatus* (Table 1). The size range of these shells is also limited. This may be evidence of predator selection or, alternatively, a product of the taphonomy of the site; there is an extremely large number, and proportion, of unidentifiable shell fragments present (Table 1; Fig. 2A). The West Stack deposit also contains an incomplete *T. torquatus* operculum, a rocky shore gastropod that became locally extinct at the end of the Last Interglacial period (Valentine 1965). The presence of this fossil provides a minimum age (older than Holocene) for the deposit. Examination of a disaggregated calcrete matrix sample (10 grams) revealed no Foraminifera. Specimens of *Ammonia* (2 individuals) and *Lamellodiscorbis* (14 individuals) were identified in thin sections but could not be identified to species level. The apparent near absence of Foraminifera in the sediment supports a terrestrial origin for the deposit (aquatic sediments contain tens to hundreds of individuals per gram; Gill et al 1991).

The Headland Deposit

This deposit contains a high diversity of species, although the counts of those species are relatively small (Table 2). It is an unusual assemblage as it contains species from several environments. Common rocky coast species are present and all currently occur in western Victoria. A group of smaller gastropods inhabits estuaries or saline lakes away from direct marine influence. The site yielded a single otolith of the marine fish *Argyrosomus hololepidotus* (Lacepede, 1801) (or mulloway) which often enters estuaries. Based on the size of otoliths of this species the one found in the deposit is from a fish 70 -90cm in length with a mass of 3.5 -5.5kg. Another component of this assemblage is a collection of terrestrial gastropods. These species all inhabit drier coastal woodland or heath environments.

Foraminifera collected from this layer are predominantly open estuary/intertidal species (Table 3). Their low abundances in the calcarenite indicate they were transported by wind along with sand grains from nearby aquatic environments. *Ammonia aoteana* Finlay, 1940 is widely distributed in brackish environments but is also abundant intertidally. Although the source environment of *A. aoteana* may differ the taphonomic characteristics of these specimens were largely similar to those of the other species suggesting they may have been exposed to similar environmental conditions. Identification of *Lamellodiscorbis dimidiatus* (Jones and Parker, 1862) was based on information from Hansen and Revets (1992). Identification of *A. aoteana* was based on a revised taxonomy of the genus *Ammonia* (Strotz 2003). The *Elphidium* sp. present in the calcarenite layer is most likely *E. crispum crispum*, Linné, 1758 however the umbonal boss (Hayward et al 1997) is only visible in the better preserved specimens. Very few *Quinqueloculina* sp. (Yassini and Jones 1995) were found in sediment from the calarenite layer and those that were present lacked distinguishable features, such as the aperture. Thus, identification to species level was not possible in this case. All species identified in sediment from the calcarenite layer are Recent forms.

SEA LEVEL AT THE TIME OF DEPOSITION OF THE SHELL DEPOSIT

Stability of the SE Australian crust since deposition of the shell deposit

Accumulation of marine shells and remains of other species at Point Ritchie requires that the headland was located in close proximity to the coast of the time. Based on sea level curves for the last 140,000 years (Fig. 4) there are three higher sea level stands between 80ka and 125ka when sea level was within 30m of the present.

When interpreting palaeosealevel data however the effect of uplift or subsidence must be considered as this can impact significantly on apparent high or low sea level stands. The southern Australian coastline is a passive continental margin situated in a tectonically stable intraplate setting (Murray-Wallace 2002). It is therefore much less susceptible to tectonic uplift than sites located in tectonically active zones such as the Huon Peninsula, Papua New Guinea (Lambeck and Chappell 2001) or Ryukyus Island, Japan (Sasaki et al 2004). It is also a far-field site, meaning it is not in close proximity to the location of former ice sheets present during glacial maxima (Murray-Wallace 2002). Sea level change in

SPECIES	COUNT*	SIZE RANGE^	HABITAT/ ENVIRONMENT[a]
Turbo undulatus (Lightfoot, 1786) *Turbo undulatus* (operculum)	10 1	2.80 – 4.60 cm 1.90 cm	Common on rocks in the lower littoral zone and infralittoral fringe on medium – high energy coasts to 6m depth.
Hipponyx conicus (Schumacher, 1817)	4	1.10 – 1.40 cm	Common on southern Australian reefs attached to *Turbo* spp., *Haliotis* spp., *Pleuroploca australasia*, *Pterynotus triformis*, *Chlamys bifrons* and *Pinna*.
Plaxiphora albida (Blainville, 1825) plate	7	1.90 – 3.00 cm	Rocky coasts.
Haliotis sp.	1	7 cm	Common on sub-tidal reef.
Salinator fragilis (Lamarck, 1822)	1 (juv.)	0.30 cm	Southeast Australian coast mid – upper littoral zone in sheltered marine inlets on mud and seagrass flats.
Hydrococcus brazieri Tenison Woods, 1876	4	0.15 – 0.21 cm	Common in saltmarsh areas of southern Australia – marginal salt lakes, back dune swamps, estuaries and tidal flats. Although requiring coverage by sea water at intervals they are found well above the high neap tide mark. They have a wide temperature and salinity tolerance.
Batillaria (Batillariella) estuarina (Tate, 1893)	2	0.90 – 1.60 cm	Estuaries.
Succinea (Austrosuccinea) australis (Ferussac, 1821)	4	0.81 – 0.98 cm	Not aquatic but mainly found in damp, even semi-aquatic environments.
Coxiella striata (Reeve, 1842)	4	0.60 – 0.85 cm	Found in western Victoria, eastern South Australia, eastern Bass Strait islands and south and eastern Tasmania. Saline lakes usually away from direct marine influence.
Magilaoma penolensis (Cox, 1868)	5	0.15 – 0.21 cm	Found throughout southeastern Australia in litter and ground vegetation in drier and coastal areas.
Pernagera officeri (Legrand, 1871)	16	0.31 – 0.40 cm	Found in southern Victoria, eastern Bass Strait islands and northern Tasmania in litter and underground vegetation in dry scrub and heath areas.
Strangesta gawleri (Brazier, 1872)	8	0.90 – 1.20 cm	Found in southeastern South Australia and southwestern Victoria under ground cover, dry forest to woodland scrub and coastal heath.
Limpet (Family Acmaeidae)	1	1.8 cm	Inhabit the shore region attached to rocks, algae or other animals.
Ozius truncatus[b] Milne-Edwards, 1834	3	3.80 cm	Found from southern Western Australia along the southern Australian coast north to southern Queensland. Can be quite common on the intertidal and very shallow subtidal rocky shores of southern Australia.
Argyrosomus hololepidotus (Lacepede, 1801) otolith	1	2.10 cm	Inhabit shallow seas and often enter estuaries.
Sponge spicules	2	0.10 cm	Aquatic.

* Shells counted possessed a columella and had one or more whorls intact. This gives a minimum estimate of the number of individuals. Counts made of specimens collected by Edmund Gill, John Sherwood and Hannah Nair.

^ *Turbo undulatus* shells and operculae, *Turbo torquatus* shells and operculae, limpets, bivalves, *Plaxiphora albida* plates, *Hipponyx conicus*, *Strangesta gawleri*, *Pernagera officeri*, *Salinator fragilis*, *Hydrococcus brazieri*, *Batillaria estuarina*, *Magilaoma penolensis* measured at widest point. Length of *Thais orbita*, *Succinea australis*, *Coxiella striata* shells, *Ozius truncatus* claw fragments, *Argyrosomus hololepidotus* otolith measured.

[a] Jones & Morgan 1994; Ludbrook 1984; Smith & Kershaw 1979; Thomson 1977; Macpherson & Gabriel 1962.

[b] Single claw/portion of claw count; most complete claw portion measurement noted.

Table 2. Headland Deposit species, their size ranges and habitat preferences.

SPECIES	COUNT[c] (orgs/g sediment)	HABITAT/ENVIRONMENT[f]
Ammonia aoteana Finlay, 1940	0.47	Widely distributed in brackish – slightly brackish environments but not restricted to such environments. Often abundant intertidally and subtidally.
Elphidium sp.[g] Linné, 1758	0.64	Open estuaries, intertidal zone of inner shelf (0-20m depth), normal salinity.
Lamellodiscorbis dimidiatus (Jones and Parker, 1862)	0.56	Open estuaries, intertidal zone. Greatest abundance in normal salinity conditions, exposed, high energy coarse substrates at shallow inner-shelf depths.
Lamellodiscorbis sp.[d]	-	As for *L. dimidiatus*.
Quinqueloculina sp.	0.05	Open estuaries, intertidal zone of inner shelf.
Unidentifiable individuals[e]	1.20	

c specimens in 100g of sediment counted
d 14 detected in thin sections. No other *Lamellodiscorbis* taxa in picked samples so likely these are *L. dimidiatus*.
e These samples possessed a lenticular shape and evidence of chambers however they were too worn to have their diagnostic features intact.
f Hayward et al 1997; Yassini & Jones 1995.
g Most likely *Elphidium crispum crispum* (see text).

Table 3. Foraminifera found in the headland deposit.

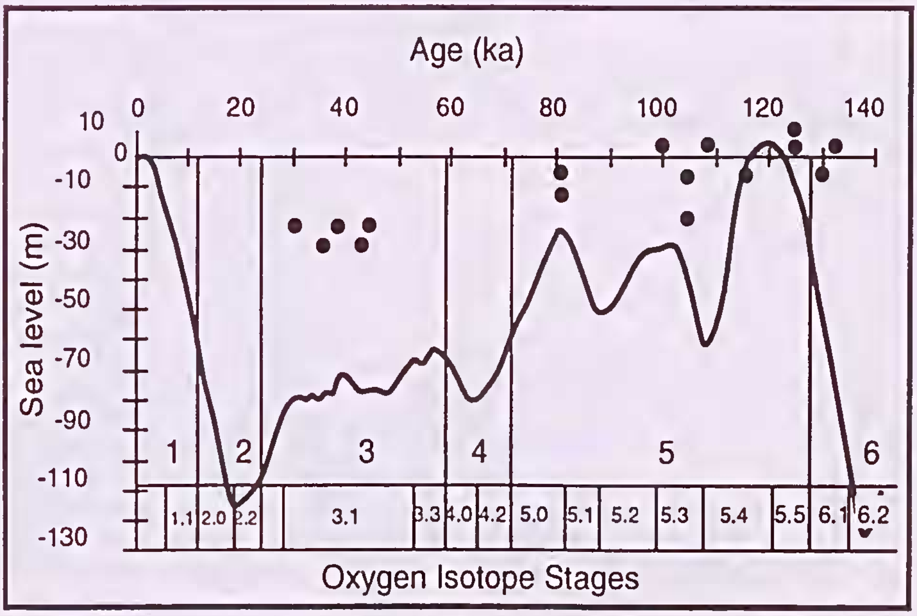


Fig. 4. Relative sea level at Huon Peninsula, Papua New Guinea (adapted from Oyston 1996 and based on Lambeck & Chappell 2001; Chappell and Shackleton 1986) with sea level data from southern Australia (solid points, references below). Oxygen isotope stages (Chappell 1983) are represented in the OIS scale bar at the bottom of the graph. Sea level data from southern Australia: Gill and Amin 1975, Warrnambool; Hails et al 1984, Spencer Gulf, SA; Schwebel 1984, Coorong Coastal Plain; Murray-Wallace 2002, Coorong Coastal Plain; Murray-Wallace et al 2001, Coorong Coastal Plain; Cann et al 1988, Gulf St. Vincent, SA; Cann et al 1993, Gulf St. Vincent, SA; Murray-Wallace et al 1993, Gulf St. Vincent, SA.

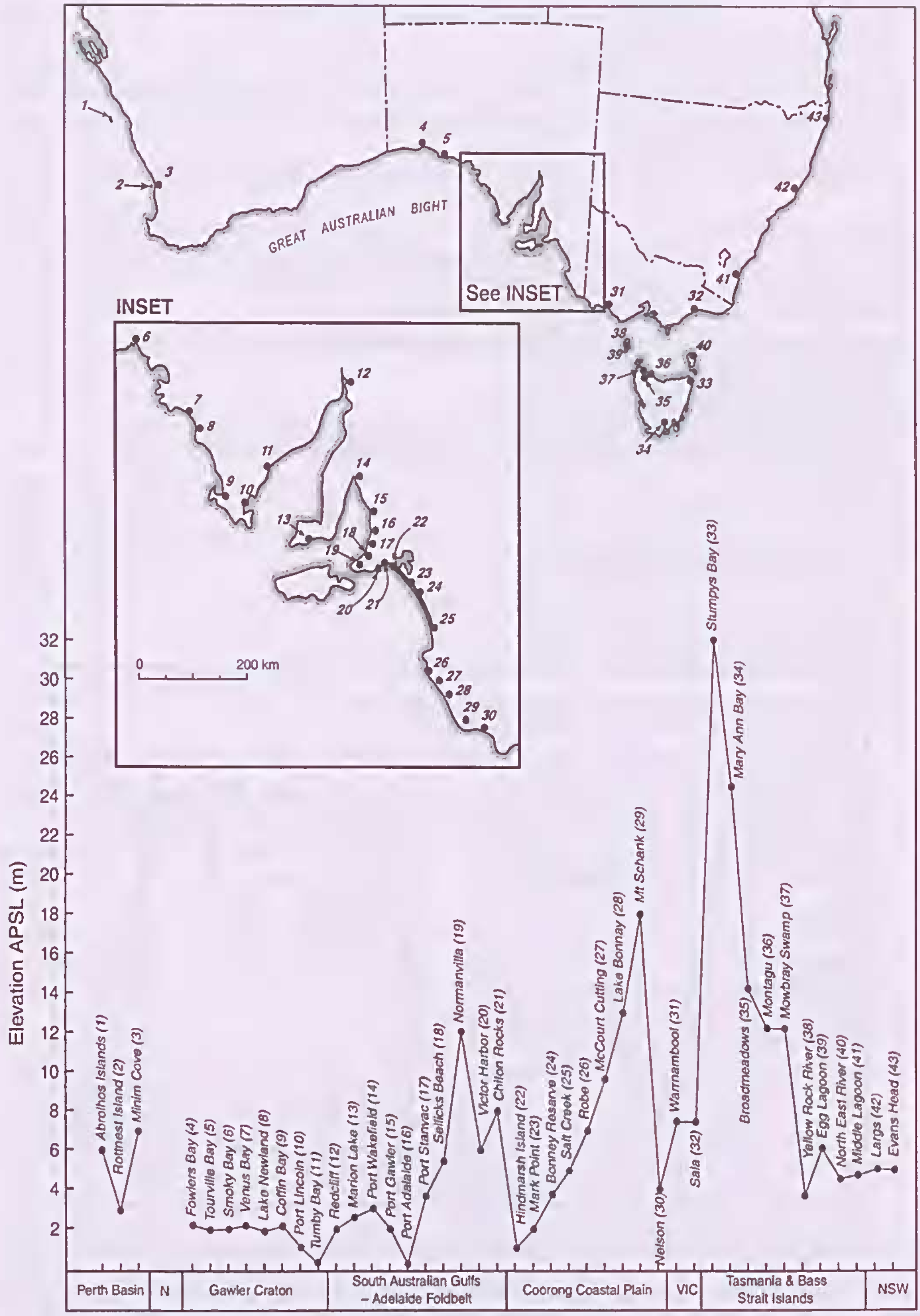


Fig. 5. Last Interglacial shoreline elevations across SE Australia (Murray-Wallace 2002).

far-field sites is generally glacio-eustatic in origin and is modulated by local hydro-isostatic effects (Nakada and Lambeck 1989).

The dune morphology of the Robe and Woakwine Ranges, part of the Coorong Coastal Plain, is similar to that seen in Pleistocene dune lines in the Warrnambool area. The Warrnambool, Robe and Woakwine dunes contain calcrete and terra rossa soil horizons (Cann et al 1999; Oyston 1996). Analogous stratigraphic formations can also be traced from the Eyre Peninsula east into western Victoria. Sediments in the Glanville Formation (Eyre Peninsula region) were deposited during the Last Interglacial maximum sea level stand and have been dated at 110 (+19/-17)ka by Belperio (1985). The Bridgewater Formation and Woakwine Barrier (Coorong Coastal Plain) contain aeolian facies of equivalent age (Hails et al 1984). Extending into western Victoria, the Woakwine Barrier is represented by a dune aeolianite, the Dennington Sand (Murray-Wallace 2002). Equivalent facies can thus be followed from the stable Eyre Peninsula through to the Warrnambool area in western Victoria. Last Interglacial sea level and the varying degrees of local uplift/subsidence can thus be compared on a regional scale.

Although the southern Australian coastline is considered relatively tectonically stable (Cann et al 1993; Gill and Amin 1975; Haworth et al 2002) regional variations in uplift and subsidence do occur (Fig. 5). Sites of Quaternary volcanism show elevated Last Interglacial marine deposits. This is largely due to regional epeirogenic uplift (Murray-Wallace 2002) caused by magma accumulation (Cann et al 1999). Raised marine deposits up to 18m above present sea level have been observed along the coast south of Mount Schank and Mount Gambier, South Australia – volcanoes active during the Quaternary (Cann et al 1999; Murray-Wallace et al 1996). South Australia's Fleurieu Peninsula is situated on the Adelaide Foldbelt and ongoing uplift in this region accounts for an apparently higher Last Interglacial sea level stand (+6 m, Murray-Wallace and Belperio 1991) during the Pleistocene (Belperio 1995). However, South Australia's Eyre Peninsula is situated on the stable Gawler Craton and provides the most consistent record of Pleistocene sea level history in Australia, with a level of +2 m for the Last Interglacial (Murray-Wallace and Belperio 1991).

While the peninsulas mentioned above are currently undergoing uplift or are stable, Gulf St Vincent and Spencer Gulf have a record of subsidence (Belperio 1995). The Coorong Coastal Plain is affected by minor uplift; Belperio and Cann (1990) calculated an uplift rate of 0.07mm/yr for this region and Last Interglacial raised marine deposits (8m to 10m above present sea level) are consistent with such a rate of uplift (Murray-Wallace and Belperio 1991). Quaternary uplift in this region may be due to its proximity to volcanism at Mount Gambier (Sprigg 1952).

Gill and Amin (1975) argue the coastline at Warrnambool is stable and free of uplift as it sits on top of a stable geophysical block, the Warrnambool Platform, or Warrnambool High, and the Miocene marine strata in the area remain horizontal. While it is possible that there has been some localized elevation due to tectonism associated with the Tower Hill eruption this appears to be slight. It can be seen from Fig. 5 that Last Interglacial (Oxygen Isotope Substage 5e) shorelines from Warrnambool and Robe (Coorong Coastal Plain) occur at similar elevations. It is therefore unlikely that the coast at Point Ritchie has undergone significant change in elevation – i.e. the shell deposit has not been formed at a time of much lower sea level and elevated tectonically to its present position.

Last Interglacial sea levels at Warrnambool

When the measured ages of the shell deposit are compared to sea level data they indicate two possible times when sea level was within 30m of the present level – either 30 – 45ka or 80 -125ka. For much of the time between the Last Interglacial and the Holocene, sea level has been much lower (>50m) than now. However data from Gulf St Vincent provides evidence of an interstadial sea level high at 30 – 45ka (Fig. 4) when sea level rose to 22m to 30m below present (Hails et al 1984, Schwebel 1984). This interstadial is considered a less likely time of formation of the shell deposit. It is consistent with AAR and a TL age determination by Sherwood et al (1994) but not with ESR (Goede 1989) or the TL determination by Oyston (1996).

In the Warrnambool region three Last Interglacial sea levels are known from coastal or marine deposits, although these also occur at higher elevations than indicated by the Huon sea level curves (Fig. 4):

(i) Port Fairy Calcarenite – an age of 125ka for this high stand (+7.5m) was published by Gill and Amin (1975) based on U/Th results of Valentine (1965) for a marine shell deposit at Port Fairy and a wave-cut platform at Warrnambool. (i.e. oxygen isotope stages 5.4-5.5)

(ii) Marine shell deposits at 3-4m above sea level – these occur at Narrawong, Goose Lagoon and Point Ritchie (Sherwood et al 1994) and Childers Cove (Gill and Amin 1975). U/Th ages have been found for all sites except Point Ritchie and are in the range 95 -108ka. The shell deposits are postulated to be relics of a still-stand shoreline as the sea was retreating from the higher Last Interglacial Maximum sea level at 125ka (i.e. oxygen isotope stages 5.2-5.3; Gill and Amin 1975).

(iii) Dennington Sand – a dune with its base at an unknown depth below present sea level. Oyston (1996) has determined an age for the basal unit at Thunder Point Warrnambool as 82 ± 12ka – correlated with oxygen isotope stages 5.0 – 5.1 (Chappell 1983). This deposit also extends below sea level at Childers Cove and here gave TL ages of 90 ± 12ka and 105 ± 17ka (Oyston 1996).

Position of Point Ritchie in relation to the coast at the time of deposition of the Headland Deposit

Figure 6 shows bathymetric data for the Warrnambool region. The coastal shelf slopes gently to a depth of 80m. Beyond this the slope increases as the shelf descends to the edge of the continental rise. Maximum interstadial sea level at 80ka is postulated at -5m to -14m for the southern Australian region (Hails et al 1984; Schwebel 1984). This is consistent with the base of the Dennington Sand being below present sea level. In light of the data presented here Point Ritchie was most probably less than 2km from the coastline at 80ka.

The age of the deposit may be younger than the last Interglacial – i.e. within the time period 30 – 45ka. At this time sea level was much lower than the present and the coast correspondingly further away. Possible interstadial sea levels at 30 – 45ka correspond to the 20m and 30m contour lines in Figure 6. Bathymetric contour lines directly south of Warrnambool (grey circle, Fig. 6) indicate the position of a drowned valley of the Hopkins River (Oyston 1996). The position of the Hopkins River mouth at a sea level of -30m (i.e. on the 30m contour line) is also shown (circle, Fig. 6). Point Ritchie was at least 3km from the coast in the interval between 30ka and 45ka.

To form the deposit shells would need to have been transported a minimum distance of 1-2km from a rocky coast to Point Ritchie at either of the most

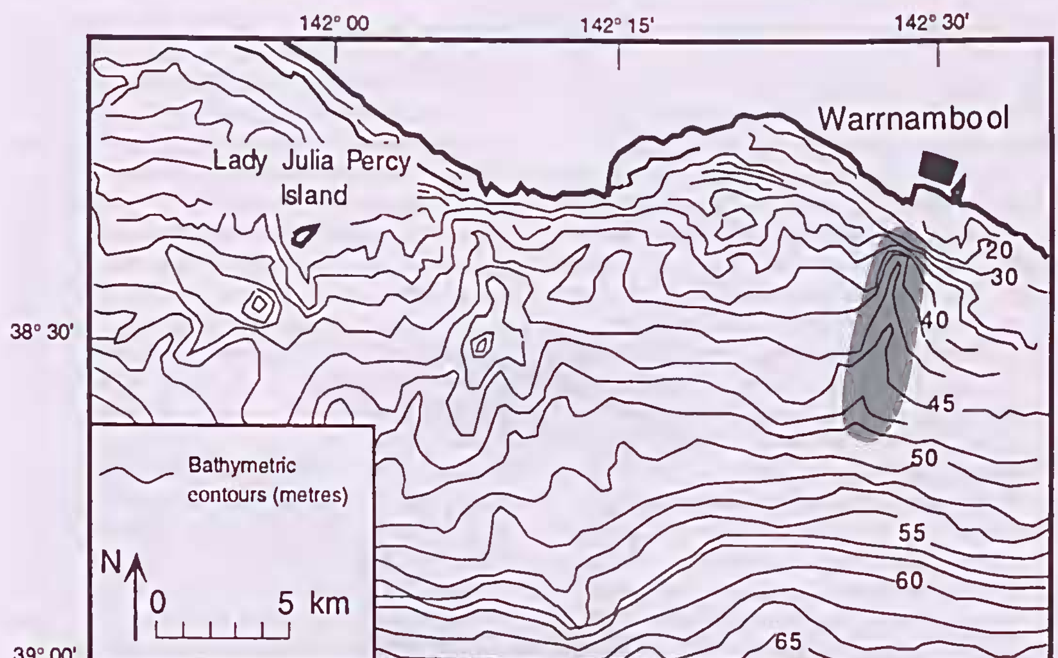


Fig. 6. Bathymetric data for the Warrnambool region showing the location of the 20m and 30m contours near Point Ritchie and a submarine valley of the Hopkins River (circled; Oyston 1996).

likely higher sea level stands (i.e. 30-45ka and ~80ka).

ORIGIN OF THE SHELL DEPOSIT

Any explanation for the origin of the shell deposit must account for its key characteristics:

(i) It is essentially a mono-specific assemblage of fragmented shells from a high energy environment.

(ii) Although high energy facies shells, they occur in a low energy facies and lack the wear, sorting and wave action sediments expected in a marine deposit.

(iii) The shells occur in a soil profile (the sub-soil of a terra rossa) and are associated with terrestrial snails and charcoal lenses.

(iv) The base of the deposit is 8m above present sea level with some shells in the headland deposit located 10m above sea level. Age determinations indicate the shell deposit was formed when sea level was lower than present.

These characteristics make hypotheses which describe natural sub-marine or shoreline origins for the shell deposit unlikely. The deposit has accumulated sub-aerially and its nature suggests selection of shells in their removal to the site. Comparison of the shell deposit age to sea level curves indicates the coastline was over 1km from the site of deposition of the shells and other marine remains. Location of a shell deposit within a few km of the coast and at least 8m above sea level at time of deposition implies transport of shell material to the site. We have considered three possible mechanisms:

(i) Transport by natural forces – a tsunami.

(ii) Transport by humans. In areas of southeastern Australia the distribution of Late Holocene Aboriginal middens indicates shellfish could be carried up to 3km from the shore where they were collected (Luebbers 1978, Godfrey 1989).

(iii) Transport by animals other than humans (e.g. seabirds are known to form shell middens).

The possibility that shells and cobbles may have been swept inland by a tsunami was discounted after investigation into the characteristics of tsunami deposits. While cobbles and shell debris deposited by a tsunami may be found many kilometres inland, tsunami deposits typically also contain a chaotic mix of large boulders, gravel, sand and shell (Bryant and Nott 2001; Bryant and Young 1996; 1992). Other depositional evidence of a tsunami includes boulders scattered through sand and incorporation of pumice into a deposit (Young et al 1995). These features are not observed in the Point Ritchie West Stack and Headland Deposits. In addition, shell material has been found above and below the middle calcrete in the western side of the Headland Deposit. Formation of the calcrete would require some time and suggests a temporary cessation of sand deposition at this location as it developed. A single event (i.e. a tsunami) could not produce shell deposits either side of the calcrete.

The problem of determining whether shell deposits are the result of natural processes or man-made ones has received scant attention in the literature (see Gill et al 1991, O'Connor and Sullivan 1994). Animals may also create middens, e.g. seals and gulls (Bowdler 1983) and these need to be distinguished if possible from man-made middens.

Table 4 presents a summary of the characteristics of man-made and animal middens, those due to tsunamis and storm beach deposits. Those of various shell deposits are compared to them:

(A) the Point Ritchie shell deposit.

(B) an Aboriginal midden at Thunder Point, Warrnambool (situated on a high energy coastline).

(C) an estuarine Aboriginal midden at Mallacoota, north-eastern Victoria.

(D) animal middens due to gulls and seals as reported by Horton (1978) and Jones and Allen (1978).

(E) storm beach lenses at Point Ritchie.

In preparing the table we have drawn on the results of Gill et al (1991).

Analysis of Table 4 makes it clear that the characteristics of anthropogenic and animal middens and natural shell deposits are not mutually exclusive. Furthermore all human middens need not share the same characteristics. A decision on the origin of a shell deposit is necessarily judgemental. The presence or absence of certain characteristics will be given different weights in forming a view on origin. Bowdler, in assessing these criteria, argues that the presence of charcoal, burnt wood, blackened shells, artefacts and hearth stones "should be sufficient guarantee of anthropogenesis" (Bowdler 1983:137). Artefacts or human skeletal material would appear to constitute positive proof for the presence of humans at a site. Unfortunately neither of these materials occurs in many shell deposits accepted as human middens (e.g. Thunder Point – B in Table 4). They do not occur in the Point Ritchie shell deposit. Other criteria such as the presence of hearth stones, charcoal and

Characteristics		Shell Deposit*				
		A	B	C	D	E
ANTHROPOGENIC MIDDENS:						
(i)	charcoal	x	x	x		
(ii)	artifacts			x		
(iii)	hearth stones	x?	x	x		
(iv)	animal bones	x		x	x	
(v)	exoskeletons of edible crustacea		x	x	x	
(vi)	burnt shell and/or crustacea	x?	x	x		
(vii)	burnt bone					
(viii)	predominantly edible species	x	x	x	x	x
(ix)	a restricted size range in edible species	x?	x	x	nd	nd
(x)	evidence of species selection	x	x	x	x	
(xi)	no internal stratification	x	x	x	x	x
MARINE SHELL DEPOSITS:						
(i)	stratification					
(ii)	sedimentary features of water laid deposits					x
(iii)	water worn pebbles/boulders			x	x?	x
(iv)	both edible and inedible species	x		x	x?	x
(v)	no evidence of species selection					x
(vi)	a full range of shell sizes	nd			nd	nd
(vii)	forms of marine life (other than mollusca) not used by man	x			x?	x
(viii)	shells often worn due to water transport			x		x
TSUNAMI DEPOSITS:						
(i)	cobbles and shell debris found many kilometers inland	x+				
(ii)	chaotic mix of gravel, boulders, sand and shell					x
(iii)	highly bimodal mixtures of coarse sand and cobbles	nd				nd
(iv)	boulders scattered through sand and pumice incorporated into deposit					

*A - Point Ritchie shell deposit
B - Thunder Point midden
C - Mallacoota midden
D - Animal middens
E - Point Ritchie storm beach lens
nd - not determined
+ - based on available sea level data

Table 4. A comparison of characteristics of middens and marine shell deposits found in various shell deposits ('x' means the characteristic is present in the deposit). Table adapted from Gill et al (1991).

blackened shell may constitute evidence for the controlled use of fire, and thus indirectly, the presence of man. Superficially, all of these characteristics occur at Point Ritchie. Attenbrow (1992) noted that charcoal can be present in natural shell deposits as a result of runoff after a fire. Discolouration of shells and pebbles may also reflect natural alteration of mineralogical composition by, for example, sub-aerial weathering or immersion in a chemically reducing sediment. Black minerals such as hydrated manganese oxides and metal sulphides and red minerals such as hydrated iron oxides may give rocks and shells a misleading appearance. The problem of proving that blackened shells have been burnt has not been seriously addressed.

Thermoluminescence has the potential to determine whether stones have been heated and, if so, the time which has elapsed since this event. In Australia the technique has already been successfully applied to Aboriginal hearths. The success of the method depends partly on the nature of the material. Burnt calcite has proved "problematic" (Bell 1983). Its application to discoloured cobbles at the Point Ritchie site suggested they had not been heated – or

if they had it was insufficient to reset their TL clocks (Sherwood et al 1994). Animal middens could contain charcoal, burnt shell and stones discoloured by heating as a result of bush fires and so this origin for the Point Ritchie deposit cannot necessarily be ruled out even should heating be proven.

The few Australian animal middens described have all contained bone (Bowdler 1983; Horton 1978; Jones and Allen 1978) as have some Aboriginal middens. If the Point Ritchie shell deposit is an animal midden, formed perhaps by a species of gull, it is an extensive one. Its size suggests the area was used fairly intensively by the species responsible. It has yielded a single fish bone (an otolith). The presence or absence of bone in a midden is unlikely to be diagnostic for animal or human middens because of uncertainty over its preservation. Factors such as scavengers, fire and weathering of bone over time may prevent its preservation in middens.

Another point of difference between animal and human middens concerns the breakage pattern of the shells (D. Witter, personal communication). Sea bird middens form as the birds obtain the meat from shellfish by dropping them onto a rocky surface from the air. Shells should thus show random breakage patterns. Shellfish broken by humans in Holocene middens show characteristic breakage patterns reproduced from shell to shell. Due to the poor state of preservation and high degree of cementation of shells at Point Ritchie it was not possible to obtain enough undisturbed, basically whole *Turbo* shells to test this.

CONCLUSION

The Point Ritchie shell deposit shows strong evidence for predatory selection of molluscan species. It resembles Aboriginal middens in many respects but lacks conclusive proof in the form of artefacts or human skeletal material. The presence of features suggesting the controlled use of fire has high-lighted the difficulty of proving shells and stones have been affected by heat. Involvement of other animals in the shell deposit's formation cannot be conclusively ruled out.

Resolution of the problems raised here may benefit archaeology by refining methodologies for the identification of human middens. It is to be hoped that the conclusion of Jones and Allen (1978) is unduly pessimistic:

> "At a certain point it might become genuinely impossible to distinguish between the snack of a bird or a man" (page 144)

If the site is human it is one of the earliest known in Australia.

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